

REMARKS

In view of the above amendments and the following remarks, reconsideration of the rejections contained in the Office Action of April 11, 2008 is respectfully requested.

By this Amendment, claims 1-72 have been cancelled and new claims 73-82 have been added and are currently pending in the application. No new matter has been added by these amendments.

The entire specification and abstract have been reviewed and revised. Due to the number of revisions, the amendments to the specification and abstract have been incorporated into the attached substitute specification and abstract. For the Examiner's benefit, a marked-up copy of the specification and abstract indicating the changes made thereto is also enclosed. No new matter has been added by the revisions. Entry of the substitute specification is thus respectfully requested.

On pages 2-3 of the Office Action, the Examiner rejected claims 37-72 under 35 U.S.C. § 112, second paragraph, as being indefinite. In particular, the Examiner asserted that the claims include phrases which are unclear and render the scope of the claims vague and indefinite. In order to address these formal rejections, and in order to place the original claims in a proper form according to U.S. practice, the original claims have been cancelled and replaced with new claims 73-82, and the new claims have been drafted so as to fully comply with all the requirements of 35 U.S.C. § 112. Therefore, it is respectfully submitted that the Examiner's formal rejections under § 112 are not applicable to the new claims.

On page 4 of the Office Action, the Examiner rejected claims 37-40, 45-49, 54-58, 63-66 and 71-72 under 35 U.S.C. § 102(b) as being anticipated by Maenishi et al. (US 6,289,582). On pages 4-5 of the Office Action, the Examiner rejected claims 37-40, 45-49, 54-58, 63-66 and 71-72 under 35 U.S.C. § 102(e) as being anticipated by Kuribayashi et al. (US 7,020,956). Further, on pages 5-7 of the Office Action, the Examiner rejected claims 41-44, 50-53, 59-62 and 67-70 under 35 U.S.C. § 103(a) as being unpatentable over Maenishi or Kuribayashi in view of Minerath III et al. (US 7,066,006). However, as indicated above, claims 1-72 have been cancelled and replaced with new claims 73-82. For the reasons discussed below, it is respectfully submitted that the new claims are clearly patentable over the prior art of record.

New independent claim 73 recites a component mounting order optimization method executed before carrying out a component mounting operation in which a plurality of component supply parts are each to be disposed at a component holding position, each component supply part holding a plurality of components, with the component supply parts being arranged in parallel and arranged movably for supplying the components, and in which the components of the component supply parts are each to be transferred to a component mounting position, and in which each component is to be mounted to a corresponding mounting point on a corresponding circuit board of a plurality of circuit boards with the corresponding circuit board being disposed at the component mounting position by moving the corresponding circuit board in X-axis and Y-axis directions. The method of claim 73 includes *representing each mounting point in a three dimensional space with an X-axis component and a Y-axis component corresponding to a location on a surface of the corresponding circuit board, and with a Z-axis component being a Z-number corresponding to a location of a corresponding component supply part in a loading arrangement of the component supply parts*, wherein the circuit boards are arranged along the Z-axis in accordance with Z-numbers of the component supply parts.

Further, claim 73 recites *comparing (1) a length of a first component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in an initial loading arrangement, with (2) a length of a second component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in a modified loading arrangement*, so as to determine a shorter of the first and second component mounting paths. The method of claim 73 also includes determining an optimized loading arrangement of the component supply parts and a component mounting order on the circuit boards by adopting the loading arrangement corresponding to the shorter component mounting path so as to determine an optimized component mounting path.

New independent claim 80 recites a component mounting order optimization program for making a computer execute a component mounting order optimization method in a component mounting operation in which a plurality of component supply parts are each to be disposed at a component holding position, each component supply part holding a plurality of components, with the component supply parts being arranged in parallel and arranged movably for supplying the

components, and in which the components of the component supply parts are each to be transferred to a component mounting position, and in which each component is to be mounted to a corresponding mounting point on a corresponding circuit board of a plurality of circuit boards with the corresponding circuit board being disposed at the component mounting position by moving the corresponding circuit board in X-axis and Y-axis directions, the program being recorded on a computer readable recording medium. The component mounting order optimization method of claim 80 includes *representing each mounting point in a three dimensional space with an X-axis component and a Y-axis component corresponding to a location on a surface of the corresponding circuit board, and with a Z-axis component being a Z-number corresponding to a location of a corresponding component supply part in a loading arrangement of the component supply parts*, wherein the circuit boards are arranged along the Z-axis in accordance with Z-numbers of the component supply parts.

Further, claim 80 recites *comparing (1) a length of a first component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in an initial loading arrangement, with (2) a length of a second component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in a modified loading arrangement*, so as to determine a shorter of the first and second component mounting paths. The component mounting order optimization method of claim 80 also includes determining an optimized loading arrangement of the component supply parts and a component mounting order on the circuit boards by adopting the loading arrangement corresponding to the shorter component mounting path so as to determine an optimized component mounting path.

New independent claim 81 recites a computer readable recording medium having a program stored thereon for making a computer execute a component mounting order optimization method in a component mounting operation in which a plurality of component supply parts are each to be disposed at a component holding position, each component supply part holding a plurality of components, with the component supply parts being arranged in parallel and arranged movably for supplying the components, and in which the components of the component supply parts are each to be transferred to a component mounting position, and in

which each component is to be mounted to a corresponding mounting point on a corresponding circuit board of a plurality of circuit boards with the corresponding circuit board being disposed at the component mounting position by moving the corresponding circuit board in X-axis and Y-axis directions. The component mounting order optimization method of claim 81 includes *representing each mounting point in a three dimensional space with an X-axis component and a Y-axis component corresponding to a location on a surface of the corresponding circuit board, and with a Z-axis component being a Z-number corresponding to a location of a corresponding component supply part in a loading arrangement of the component supply parts*, wherein the circuit boards are arranged along the Z-axis in accordance with Z-numbers of the component supply parts.

Further, claim 81 recites *comparing (1) a length of a first component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in an initial loading arrangement, with (2) a length of a second component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in a modified loading arrangement*, so as to determine a shorter of the first and second component mounting paths. The component mounting order optimization method of claim 81 also includes determining an optimized loading arrangement of the component supply parts and a component mounting order on the circuit boards by adopting the loading arrangement corresponding to the shorter component mounting path so as to determine an optimized component mounting path.

New independent claim 82 recites a component mounting apparatus which includes a component supply unit having a plurality of component supply parts, each component supply part holding a plurality of components, wherein the component supply parts are each to be disposed at a component holding position, the component supply parts being arranged in parallel and arranged movably for supplying the components. The component mounting apparatus of claim 82 also includes a component shift device having a component holder, the component shift device being operable to transfer the component holder between the component holding position and a component mounting position, the component shift device being arranged to hold the components supplied from the component supply parts by the component holder and to mount

each component to a corresponding mounting point on a corresponding circuit board of a plurality of circuit boards, with the corresponding circuit board being disposed at the component mounting position.

Further, claim 82 recites a controller for optimizing a mounting operation of the components, with the controller including *an arrangement optimizing part for representing each mounting point in a three dimensional space with an X-axis component and a Y-axis component corresponding to a location on a surface of the corresponding circuit board, and with a Z-axis component being a Z-number corresponding to a location of a corresponding component supply part in a loading arrangement of the component supply parts, wherein the circuit boards are arranged along the Z-axis in accordance with Z-numbers of the component supply parts.* In addition, claim 82 recites that the controller includes *a mounting path optimizing part for comparing (1) a length of a first component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in an initial loading arrangement, with (2) a length of a second component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in a modified loading arrangement, so as to determine a shorter of the first and second component mounting paths,* wherein the mounting path optimizing part is operable to determine an optimized loading arrangement of the component supply parts and a component mounting order on the circuit boards by adopting the loading arrangement corresponding to the shorter component mounting path so as to determine an optimized component mounting path.

Maenishi discloses a component mounting method and apparatus in which components attached to feed tape reels in the Z direction are arrayed in the Z direction based on the sequence in which the components are to be mounted to a printed board. However, Maenishi does not disclose *representing each mounting point in a three dimensional space with an X-axis component and a Y-axis component corresponding to a location on a surface of a corresponding circuit board of a plurality of circuit boards, and with a Z-axis component being a Z-number corresponding to a location of a corresponding component supply part in a loading arrangement of the component supply parts, and comparing (1) a length of a first component mounting path connecting the mounting points arranged in the three dimensional space based on the component*

supply parts being in an initial loading arrangement, with (2) a length of a second component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in a modified loading arrangement, as required by independent claims 73, 80 and 81.

Rather, Maenishi discloses arraying the components on the feed tape based on a distance between mounting points on the surface of a single mounting board, as shown in Fig. 2. Therefore, Maenishi does not disclose representing each mounting point in a three dimensional space with an X-axis component and a Y-axis component corresponding to a location on a surface of a corresponding circuit board of a plurality of circuit boards arranged along the Z-axis, and with a Z-axis component being a Z-number corresponding to a location of a corresponding component supply part in a loading arrangement of the component supply parts, and comparing lengths of component mounting paths in the three dimensional space, as required by independent claims 73, 80 and 81, because Maenishi only discloses representing and comparing mounting points in a two dimensional space.

Further, for the same reasons as discussed above, Maenishi also does not disclose a component mounting apparatus having a controller for optimizing a mounting operation of the components, with the controller including *an arrangement optimizing part for representing each mounting point in a three dimensional space with an X-axis component and a Y-axis component corresponding to a location on a surface of the corresponding circuit board, and with a Z-axis component being a Z-number corresponding to a location of a corresponding component supply part in a loading arrangement of the component supply parts, wherein the circuit boards are arranged along the Z-axis in accordance with Z-numbers of the component supply parts, and which includes a mounting path optimizing part for comparing (1) a length of a first component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in an initial loading arrangement, with (2) a length of a second component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in a modified loading arrangement, so as to determine a shorter of the first and second component mounting paths, as required by independent claim 82.*

Kuribayashi discloses a method and apparatus for feeding components in which a spare component is supplied when the absence of a component is detected at the component supply part. Kuribayashi discloses that a mounting order is reorganized to shorten the time period for changing the position of the supplying of the component when the absence is detected. However, Kuribayashi does not disclose *representing each mounting point in a three dimensional space with an X-axis component and a Y-axis component corresponding to a location on a surface of a corresponding circuit board of a plurality of circuit boards, and with a Z-axis component being a Z-number corresponding to a location of a corresponding component supply part in a loading arrangement of the component supply parts, and comparing (1) a length of a first component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in an initial loading arrangement, with (2) a length of a second component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in a modified loading arrangement, as required by independent claims 73, 80 and 81.*

Further, for the same reasons as discussed above, Kuribayashi also does not disclose a component mounting apparatus having a controller for optimizing a mounting operation of the components, with the controller including *an arrangement optimizing part for representing each mounting point in a three dimensional space with an X-axis component and a Y-axis component corresponding to a location on a surface of the corresponding circuit board, and with a Z-axis component being a Z-number corresponding to a location of a corresponding component supply part in a loading arrangement of the component supply parts, wherein the circuit boards are arranged along the Z-axis in accordance with Z-numbers of the component supply parts, and which includes a mounting path optimizing part for comparing (1) a length of a first component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in an initial loading arrangement, with (2) a length of a second component mounting path connecting the mounting points arranged in the three dimensional space based on the component supply parts being in a modified loading arrangement, so as to determine a shorter of the first and second component mounting paths, as required by independent claim 82.*

Accordingly, it is respectfully submitted that none of the Maenishi and Kuribayashi references discloses or suggests all of the limitations of independent claims 73 and 80-82.

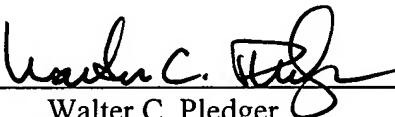
Therefore, it is respectfully submitted that independent claims 73 and 80-82, as well as claims 74-79 which depend therefrom, are clearly allowable over the prior art of record.

In view of the foregoing amendments and remarks, it is respectfully submitted that the present application is clearly in condition for allowance. An early notice to that effect is respectfully solicited.

If, after reviewing this Amendment, the Examiner feels there are any issues remaining which must be resolved before the application can be passed to issue, the Examiner is respectfully requested to contact the undersigned by telephone in order to resolve such issues.

Respectfully submitted,

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DESCRIPTION

COMPONENT MOUNTING ORDER OPTIMIZATION METHOD, COMPONENT
MOUNTING ORDER OPTIMIZATION PROGRAM, RECORDING MEDIUM FOR THE PROGRAM,
5 AND COMPONENT MOUNTING APPARATUS USING THE METHOD

TECHNICAL FIELD

The present invention relates to, for example what is
called a rotary type component mounting apparatus in which
10 component holders hold and mount components while rotating along a
circumference, and also to a method for optimizing a component
mounting order to optimize a component mounting operation carried out
by the component mounting apparatus, a program for optimizing a
component mounting order to carry out the optimization method, and
15 a computer readable recording medium with the component
mounting order optimization program recorded.

BACKGROUND ART

There is the so-called rotary type component mounting
20 apparatus 1 shown in Fig. 26. The component mounting apparatus 1 has
roughly an orthogonal table 9, a component supply unit 3, a supply

table 4, a component holding device 5, a circuit board transfer device 8, a controller 10, and a component recognizer 11. The orthogonal table 9 is a table for holding a circuit board 2 and positioning the circuit board 2 to mount electronic components onto the circuit board 2, which is movable in X and Y-directions orthogonal to each other. The component supply unit 3 is constituted of generally called reel type parts cassettes 3a each with a mechanism for supplying electronic components continuously from a reel where a tape with the electronic components stored therein is wound, having a plurality of the parts cassettes 3a arranged side by side along the X-direction as indicated in the drawing. The supply table 4 with the component supply unit 3 equipped detachably thereto is movable in the X-direction along a rail 6 extending in the X-direction. To the supply table 4 are allotted unique numbers (referred to as Z-numbers hereinafter) respectively for recognizing positions in the X-direction where the parts cassettes 3a are loaded.

In the component holding device 5, a plurality of mounting heads 5a and a plurality of nozzles 5b equipped with each mounting head 5a for holding electronic components by suction are fitted to the so-called rotary head type cylindrical rotary body. The component

holding device 5 rotates in a direction about a rotational center axis as indicated by an arrow 7 although being prevented from moving in the X and Y-directions. Each of the nozzles 5b is movable up and down in a direction in which the nozzle extends. The circuit board transfer device 8 is a device for carrying a circuit board 2 into the component mounting apparatus 1 and carrying the circuit board 2 out of the component mounting apparatus 1. The controller 10 controls the operation of each of the above constituent parts to control an electronic component mounting operation to circuit board 2. The component recognizer 11 is a device for imaging a holding posture of the electronic component at nozzle 5b before the electronic component after being held by nozzle 5b from the parts cassette 3a is mounted to the circuit board 2.

The electronic components are mounted in the following manner in the component mounting apparatus 1 constituted as above. Since the component holding device 5 is unmovable in the X and Y-directions as depicted hereinabove, the supply table 4 moves the parts cassette 3a having desired electronic components to be mounted to the circuit board 2 to a component holding position where the electronic components can be sucked by the nozzles 5b. Meanwhile, the orthogonal table 9 moves in the X and Y-directions so that the

nozzle 5b holding the electronic component is positioned to desired mounting position on the circuit board 2. The nozzle 5b of the component holding device 5 rotates in the direction about the axis along the arrow 7 after holding the electronic component from the positioned parts cassette 3a. The component recognizer 11 images the holding posture in a halfway of the rotation. The nozzle 5b moves to above the mounting positions by the rotation. The component holding device 5 lowers the nozzle 5b to mount the electronic component to the mounting position. After the mounting, nozzle 5b rotates again along the arrow 7 to return to above the parts cassette 3a. The above operation is carried out for the nozzles 5b at each of the mounting heads 5a, whereby each of the electronic components is mounted onto the circuit board 2.

15 In the above component mounting apparatus 1, since the component holding device 5 rotates at a fixed point without moving in the X and Y-directions, the rotation of the nozzles 5b to above the mounting positions after the nozzles 5b hold electronic components from the parts cassettes 3a, and the rotation operation of the nozzles 20 5b until the nozzles 5b return to above the parts cassettes 3a after the electronic components are mounted are determined by mechanical

characteristics of the component holding device 5. However, the rotational speed of the holding device 5 is required to be different for electronic components to be held by the nozzles 5b so as to prevent ~~trouble of drop of~~ the electronic components from being dropped from the nozzles 5b, and the like. Moreover, it is necessary for the supply table 4 to move a desired parts cassette 3a to the component holding position so that the nozzle 5b can hold the desired electronic component as described above.

As such, in the conventional art, parts cassettes 3a for supplying electronic components for which the rotational speed of the component holding device 5 is to be equal are grouped to be a group A, a group B, ... for every rotational speed, thereby shortening a cycle time required for mounting the electronic components. In addition, parts cassettes 3a in each group are arranged at the supply table 4 so that the parts cassettes 3a with a larger number of components to be supplied are positioned to be closer to the component holding position.

In the above conventional arrangement, ~~since the~~ parts cassettes 3a in each group are arranged at the supply table 4 without being related to the mounting positions on the circuit board 2 where the electronic components are to be mounted, and therefore

a longer time is eventually consumed in some cases from holding the component to mounting the component.

DISCLOSURE SUMMARY OF INVENTION

5 The present invention is devised to solve the
aforementioned problem and has for its object to provide a
component mounting order optimization method, a component
mounting order optimization program, a computer readable
recording medium with a component mounting order optimization program
10 recorded, and a component mounting apparatus whereby the mounting time
can be shortened as compared with the conventional art.

In order to accomplish the above objective, the
present invention is constituted as described herein.

According to a first aspect of the present invention,
15 there is provided a component mounting order optimization method
executed before carrying out a component mounting operation in which
a component is held from one component supply part disposed at a
component holding position among a plurality of component supply parts
arranged in parallel and arranged movably for
20 supplying components, is transferred to a component mounting position,
and is mounted to a mounting point on a circuit board disposed at the

component mounting position by moving in X-axis and Y-axis directions,

the method comprising:

optimizing an arrangement of the component supply parts with position information of the mounting points taken into

5 account; and then

optimizing a component mounting path to the circuit board under the optimized arrangement of the component supply parts.

The above method of the first aspect may be designed so
10 that the optimization of the arrangement of the component supply parts is carried out by temporarily arranging the component supply parts and correcting the temporary arrangement before optimizing the component mounting path.

The above method of the first aspect may be designed so
15 that the temporary arrangement in optimizing the arrangement of the component supply parts is executed by obtaining a product of variances for each of X and Y-coordinate values and Z-values showing locations of the component supply parts in terms of the mounting points of the circuit board while the Z-value is changed, and then obtaining the
20 arrangement of the component supply parts which makes the variance product smaller.

The above method of the first aspect may be designed so that the arrangement which makes the variance product smaller is obtained by executing:

a first process of obtaining a first variance product for
5 a first arrangement of the component supply parts;

a second process of obtaining a second variance product for a second arrangement different from the first arrangement; and

a third process of comparing the first variance
10 product and the second variance product with each other and setting the smaller one as a new first variance product,

thereby obtaining a much smaller new first variance product by repeating the second process and the third process subsequently.

15 The above method of the first aspect may be designed so that for correcting the temporary arrangement in optimizing the arrangement of the component supply parts, after the component supply parts are temporarily arranged by obtaining the smaller variance product, the location of a second component supply part is changed
20 on a basis of a distance between a reference mounting position on the circuit board where the component supplied from a first component

supply part adjacent to the component holding position is to be mounted and an object mounting position on the circuit board where the component supplied from the second component supply part other than the first component supply part is to be mounted, thereby further optimizing the arrangement of the component supply parts.

The above method of the first aspect may be designed so that the changing of the location of the second component supply part comprises:

obtaining each of the distances while the second component supply part is sequentially changed; and

arranging the second component supply part which makes the distance shortest adjacent to the first component supply part.

The above method of the first aspect may be designed so that the component mounting path is optimized by selecting two mounting paths for connecting two mounting points among mounting paths, recombining the two mounting paths, and selecting the path having a shorter mounting path length through comparison between before and after the recombination, thereby executing the optimization.

The above method of the first aspect may be designed so that in order to reflect the mounting path optimized by the

recombination of mounting paths to the mounting order, after the optimization, a mounting order for the mounting points which constitute the optimized mounting path is changed.

5 The above method of the first aspect may be designed so that the component supply parts are rearranged after the optimized mounting path is reflected to the mounting order, whereby the component mounting path is optimized and reflected to the mounting order.

10 According to a second aspect of the present invention, there is provided a component mounting order optimization program for making a computer execute a component mounting order optimization method in a component mounting operation in which a component is held from one component supply part disposed at a component holding position among a plurality of component supply parts arranged in parallel and movable for supplying components, is transferred to a
15 component mounting position, and is mounted to a mounting point on a circuit board disposed at the component mounting position by moving in X-axis and Y-axis directions,

the program comprising:

20 a procedure of optimizing an arrangement of the component supply parts with position information of the mounting points taken

into account; and

a procedure of optimizing a component mounting path to the circuit board under the optimized arrangement of the component supply parts.

5 According to a third aspect of the present invention, there is provided a computer readable recording medium with a program stored for making a computer execute a component mounting order optimization method in a component mounting operation in which a component is held from one component supply part disposed at a
10 component holding position among a plurality of component supply parts arranged in parallel and movable for supplying components, is transferred to a component mounting position, and is mounted to a mounting point on a circuit board disposed at the component mounting position by moving in X-axis and Y-axis directions,

15 the recording medium having the program for executing:

a procedure of optimizing an arrangement of the component supply parts with position information of mounting points taken into account; and

a procedure of optimizing a component mounting path to
20 the circuit board under the optimized arrangement of the component supply parts.

According to a fourth aspect of the present invention,
there is provided a component mounting apparatus comprising:

a component supply unit having a plurality of supply parts
arranged in parallel for supplying components, for supplying
5 components from one of the supply parts positioned to a component
holding position;

a component shift device having a component holder, for
transferring the component holder between the component
holding position and a component mounting position, holding
10 components supplied from the supply parts by the component holders
and mounting the components to mounting points on a circuit board at
the component mounting position;

an orthogonal table for holding the circuit board and
moving the circuit board in X and Y-axes directions, thereby
15 locating the mounting points to the component mounting position; and

a controller for optimizing a mounting operation of the
components to the circuit board from the supply parts, which includes
an arrangement optimizing part for optimizing an arrangement of the
supply parts with position information of the mounting points taken
20 into account, and a mounting path optimizing part for optimizing a
component mounting path to the circuit board under the optimized

arrangement of the supply parts.

The above apparatus of the fourth aspect may be designed so that the arrangement optimizing part obtains a product of three variances of each of X and Y-coordinate values and Z-values
5 showing locations of the supply parts while the Z-value is changed in terms of the mounting points on the circuit board, and obtains the arrangement of the component supply parts which makes the variance product smaller.

The above apparatus of the fourth aspect may be
10 designed so that the arrangement optimizing part obtains the arrangement which makes the variance product smaller by obtaining a first variance product for a first arrangement of the supply parts, obtaining a second variance product for a second arrangement different from the first arrangement, comparing the first variance product and
15 the second variance product with each other to set the smaller one as a new first variance product, and obtaining a much smaller variance product as a new first variance product by repeating the comparison.

The above apparatus of the fourth aspect may be designed so that the arrangement optimizing part further optimizes
20 the arrangement of the supply parts, after optimizing the arrangement of the supply parts by obtaining the smaller variance product, caused

by changing a location of a second supply part on a basis of a distance between a reference mounting position where the component supplied from a first supply part adjacent to the component holding position is to be mounted and an object mounting position where the component
5 supplied from the second supply part other than the first supply part is to be mounted.

The above apparatus of the fourth aspect may be designed so that for changing the location of the second supply part, the distance is obtained while the second supply part is sequentially
10 changed and the second supply part which makes the distance shortest is arranged adjacent to the first supply part.

The above apparatus of the fourth aspect may be designed so that the mounting path optimizing part optimizes by selecting two among mounting paths for connecting two mounting points,
15 recombining the two mounting paths, and selecting the path having a shorter mounting path length through comparison between before and after the recombination.

The above apparatus of the fourth aspect may be designed so that the mounting path optimizing part changes a
20 mounting order of mounting points which constitute a new mounting path after the recombination of mounting paths, in accordance with the new

mounting path.

The above apparatus of the fourth aspect may be designed so that the controller optimizes the component mounting path again by rearranging the supply parts after the component mounting
5 path is optimized.

According to the component mounting order optimization method of the first aspect, the component mounting order optimization program of the second aspect, the recording medium of the third aspect and the component mounting apparatus of the fourth aspect of the
10 present invention, there are provided the component supply unit, the component shift device and the controller, whereby the mounting path to the circuit board is optimized under the arrangement of component supply parts installed in the component supply unit after the arrangement is optimized by the controller while position information
15 of mounting points of the circuit board is taken into account. Since the position information of the mounting points is taken into account when the arrangement of the component supply parts is to be obtained, wasteful mounting paths are reduced and the mounting time can be shortened in comparison with the conventional art in which the
20 mounting path only on the circuit board is optimized.

A product of variances is used as a means for optimizing

the arrangement of the component supply parts, whereby the distribution of mounting points in three dimensions including the arrangement of the component supply parts can be concentrated easily.

After the arrangement of the component supply parts is
5 obtained with the use of the variance product, the arrangement of the component supply parts is corrected on the basis of the mounting path length to be taken when the electronic components are mounted from the component supply parts disposed by the arrangement. This correction operation enables obtaining a more appropriate arrangement
10 of the component supply parts, reducing wasteful mounting paths more and shortening the mounting time.

The mounting path to the circuit board is optimized under the optimized arrangement of the component supply parts. Wasteful mounting paths are thus reduced, so that the mounting time can be
15 shortened. Further, for optimizing the mounting path, two unit paths are recombined and the path having a shorter mounting path length through comparison between before and after the recombination is adopted, thus facilitating detecting the much shorter path.

The arrangement of the component supply parts is
20 considered again after the mounting path is optimized as above, whereby the mounting path is optimized again, and the mounting time

can be shortened furthermore.

BRIEF DESCRIPTION OF DRAWINGS

These and other aspects and features of the present
5 invention will become clear from the following description taken in
conjunction with the preferred embodiments thereof with reference to
the accompanying drawings, in which:

Fig. 1 is a flow chart showing a component mounting order
optimization method according to one preferred embodiment of the
10 present invention;

Fig. 2 is a diagram explanatory of the operation of step
100 in Fig. 1;

Fig. 3 is a diagram explanatory of the operation of step
100 in Fig. 1 and having a partial changeover from Fig. 2;

15 Fig. 4 is a diagram explanatory of the operation of step
200 in Fig. 1, namely, a diagram of each mounting point seen in plan
from an arrow direction of Fig. 3;

Fig. 5 is a flow chart explanatory of the operation of
step 100 in Fig. 1 in detail;

20 Fig. 6 is a diagram explanatory of the operation of step
200 in Fig. 1, namely, explanatory of a relation between an arrangement

of parts cassettes and mounting points of a circuit board;

Fig. 7 is a flow chart explanatory of the operation of step 200 in Fig. 1 in detail;

Fig. 8 is a diagram supplementally explanatory of the operation of step 207 in Fig. 7;

Fig. 9 is a flow chart explanatory of the operation of step 300 in Fig. 1 in detail;

Fig. 10 is a flow chart explanatory of the operation of step 307 in Fig. 9 in detail;

Fig. 11 is a flow chart explanatory of the operation of step 307 in Fig. 9 in detail;

Fig. 12 is a diagram specifically explanatory of recombination of mounting paths depicted in Figs. 10 and 11;

Fig. 13 is a diagram specifically explanatory of the recombination of mounting paths depicted in Figs. 10 and 11;

Fig. 14 is a diagram specifically explanatory of the recombination of mounting paths depicted in Figs. 10 and 11;

Fig. 15 is a diagram showing a mounting path before the recombined by operations in Figs. 10 and 11;

Fig. 16 is a diagram showing a mounting path after recombined with the mounting path shown in Fig. 15, explanatory of

the necessity of reflecting the mounting path to a mounting order;

Fig. 17 is a diagram in which a mounting path after recombined with the mounting path of Fig. 16 is reflected to the mounting order;

5 Fig. 18 is a diagram showing a relation between the mounting order and mounting points shown in Fig. 17;

Fig. 19 is a flow chart explanatory of the operation of step 400 in Fig. 1 in detail;

Fig. 20 is a flow chart explanatory of the operation of
10 step 400 in Fig. 1 in detail;

Fig. 21 is a perspective view of a component mounting apparatus for carrying out the component mounting order optimization method of the embodiment shown in Fig. 1;

Fig. 22 is a plan view showing a component supply unit,
15 a component shift device and the like parts in Fig. 21 more in detail;

Fig. 23 is a diagram of an example of an arrangement of parts cassettes in the component supply unit of Fig. 21;

Fig. 24 is a diagram explanatory of relations from a view point of control at a controller shown in Fig. 21;

20 Fig. 25 is a diagram explanatory of an effect when the component mounting order optimization method of the embodiment shown

in Fig. 1 is carried out;

Fig. 26 is a perspective view of a conventional component mounting apparatus; and

Fig. 27 is a plan view showing a component supply unit,
5 a component shift device and the like parts of Fig. 26 more in detail.

~~BEST MODE FOR CARRYING OUT~~ DETAILED DESCRIPTION OF THE INVENTION

A component mounting order optimization method, a component mounting order optimization program, a computer readable
10 recording medium with a component mounting order optimization program recorded, and a component mounting apparatus which embody the present invention will be described in detail below with reference to the attached drawings. The above component mounting order optimization program is a program for making a computer carry out the component
15 mounting order optimization method, and the component mounting apparatus is an apparatus for executing the component mounting order optimization method thereby carrying out a component mounting operation. Like constituent parts are designated by like reference numerals through the drawings.

20 The component mounting order optimization is to optimize a component mounting order so as to make a route for mounting

components shortest.

The component mounting apparatus according to one embodiment will be described first. As indicated in Figs. 21 and 22, the component mounting apparatus 101 of the present embodiment is the
5 so-called rotary type in which component holders installed to a component shift device 105 to be described below mount components while rotating on a circumference. A fundamental configuration of the apparatus 101 has a component supply unit 103, a supply table 104, the component shift device 105, and a controller 180. The component
10 mounting apparatus 101 is further provided with a circuit board transfer device 108, an orthogonal table 109, and a component recognizer 111.

The component supply unit 103 has so-called reel type parts cassettes 103a having a mechanism for continuously supplying
15 electronic components 175 from a reel where a tape with the electronic components stored therein is wound, and the supply table 104 where the parts cassettes 103a are detachably loaded and arranged in parallel in an X-axis direction. The parts cassette 3a corresponds to an example functioning as a supply part. In
20 order to execute the component mounting order optimization method of the embodiment, it is premised that at least two parts cassettes 3a

are installed. Kinds of electronic components to be supplied from parts cassettes 103a may differ for each parts cassette, or electronic components of the same kind may be supplied from a plurality of parts cassettes 103a. It does not matter what kind of electronic components is supplied from each parts cassette 103a. According to the present embodiment as well, parts cassettes 103a for supplying electronic components 175 to be rotated at the same rotational speed at the component shift device 105 are grouped into a group A, a group B, ... for every rotational speed as shown in Fig. 23 and thus arranged at the supply table 104. However, an arrangement of the parts cassettes 103 in each group is determined by an arrangement optimization method for the parts cassettes 103 to be detailed later, and the parts cassettes 103 in each group are arranged on the basis of the determination. The supply table 104 can be moved, for example, by a drive unit 104a having a ball screw mechanism along a rail 106 extending in the X-axis direction, positioning one parts cassette 103a which is to supply desired electronic components 175 to the component shift device 105, to a component holding position 171 as shown in Fig. 22. The supply table 104 has the aforementioned Z-numbers allotted thereto as unique numbers to recognize the position in the X-axis direction where each parts cassette 103 is loaded.

The component shift device 105 is the so-called rotary head type having nozzles 105b for holding electronic components 175 by suction. The nozzle 105b corresponds to an example exerting the function of the component holder. Specifically, the component shift
5 device 105 has a plurality of mounting heads 105a arranged at a circumferential edge part of a cylindrical rotary body 105c, with a plurality of nozzles 105b installed for each mounting head 105a. The component shift device 105 rotates the rotary body 105c in a direction about a rotational center axis indicated by an arrow 107 although it
10 prevents the rotary body from moving in the X-axis and a Y-axis directions. Each nozzle 105b is movable up and down in a direction along its axis. In the thus constituted component shift device 105, through the above rotation of the rotary body 105c, nozzles 105b are rotated between a component holding position 171 and a component
15 mounting position 172 positioned on the circumference of the mounting head 105a, whereby the electronic component 175 supplied by the parts cassette 3a positioned to the component holding position 171 is held by the nozzle 105b and mounted to a mounting point 173 of a circuit board 2 at the component mounting position 172.

20 The circuit board transfer device 108 is a device extending along the X-axis direction for carrying the circuit board

2 to the orthogonal table 109 and carrying the circuit board 2 out of the component mounting apparatus 101. The orthogonal table 109 is a table for holding the circuit board 2 carried in via the circuit board transfer device 108 and positioning the mounting point 173 on the circuit board 2 to the component mounting position 172 for an operation of mounting the electronic component 175 onto the circuit board 2. The orthogonal table 109 can be moved in mutually orthogonal X-axis and Y-axis directions by, for example, two drive units 109a and 109b each having a ball screw mechanism.

The component recognizer 111 is a device disposed below a rotation route of nozzles 105b of the component shift device 105 for imaging a posture of the electronic component 175 held by the nozzle 105b before the electronic component is mounted onto the circuit board 2 after the electronic component is held by the nozzle 105b from the parts cassette 103a.

The controller 180 controls, as indicated in Fig. 24, operations of each of the above constituent parts thereby controlling the operation of mounting electronic components onto the circuit board 2 in accordance with the so-called NC-program including electronic component data, circuit board data, mounting position data, mounting operation order data and the like stored in a storage 185. Furthermore,

as one of operations characteristic of the present embodiment, the controller 180 carries out an optimization operation for the component mounting order with the arrangement of parts cassettes 103a at the supply table 104 taken into account, that is, an operation for
5 obtaining a path whereby a mounting path length to the circuit board 2 becomes minimum while the arrangement of the parts cassettes 103a is taken into account. A program for carrying out the optimization operation for the component mounting order may be stored in the storage 185 beforehand, or may be recorded into a recording medium 187 such
10 as a CD-ROM and read out by a read device 186 installed in the component mounting apparatus 101. Alternatively, the program may be downloaded via a communication line to the storage 185.

Operations in the component mounting apparatus 101 constituted as above will be described hereinafter. Each of the
15 following operations is controlled by the controller 180. The mounting operation itself carried out by the component mounting apparatus 101 is not different from that in the conventional art and therefore will be omitted from the description below. Herein, the operation controlled and carried out by the controller 180 for
20 optimizing the component mounting order with the arrangement of parts cassettes 103a taken into consideration will be primarily discussed,

and yet a brief description of the component mounting operation including the optimization operation will be provided. The optimization operation for the component mounting order is an operation to be preliminarily carried out before a start of the
5 component mounting operation so as to obtain an optimized component mounting order. The optimized component mounting order thus obtained is stored in the storage 185 and is executed as one program within the NC-program by the controller 180.

The optimization method for the component mounting order
10 schematically consists of steps (indicated by "S" in the drawings) 100-400 as indicated in Fig. 1. Essential operations are steps 100-300 although it is preferred to carry out step 400.

First, step 100 will be described.

At step 100, the arrangement or layout when each parts
15 cassette 103a is loaded onto the supply table 104 of the component supply unit 103 is obtained while position information of the mounting points 173 of the circuit board 2 is taken into account when an initial arrangement of the parts cassettes 103a is obtained. Similar to the conventional example, parts cassettes 103a are grouped for every
20 rotational speed at the component shift device 105 in the present embodiment as well, and therefore the above arrangement or layout

implies obtaining an arrangement of parts cassettes 103a within each group.

As a method of obtaining the arrangement with the position information of the mounting points 173 of the circuit board 2 being
5 taken into account, an "analysis of variance" used in statistical processes is employed in the embodiment. Specifically, the method will be depicted here in relation to the case wherein, for example, electronic components supplied from the parts cassette 103a disposed at the Z-number of "1" on the supply table 104 are mounted to mounting
10 points 173-a and 173-b on the circuit board 2, an electronic component from the parts cassette 103a disposed at the Z-number of "2" is mounted to a mounting point 173-c on the circuit board 2, and electronic components from the parts cassette 103a disposed at the Z-number of "3" are mounted to mounting points 173-d and 173-e on the circuit board
15 2, as shown in Fig. 2. In this case, the mounting operation to each of the mounting points 173-a to 173-e can be represented in three dimensions as shown in Fig. 2 given that the Z-number showing the location of each parts cassette 103a is expressed by the Z-axis of a three dimensional space and a plane of the circuit board 2 is
20 expressed by the X and Y-axes. As is apparent from the comparison between Fig. 2 and Fig. 3 plotted in the same fashion as Fig. 2, the

mounting path length becomes shorter if the parts cassette 103a of the Z-number "2" is replaced with the parts cassette 103a of the Z-number "3", making the mounting operation smoother.

In the meantime, in order for simplifying the description using the three dimensions, it is possible to plot each mounting point 173 two dimensionally as indicated in Fig. 4 if three circuit boards 2 are seen together from a direction perpendicular to the circuit board 2, i.e., from an arrow 176 direction in Fig. 3. Fig. 4 is a conceptual diagram not exactly showing mounting points of Fig. 2 or 3. As will be made clear from Fig. 4 and the description related to the above replacement of Z-numbers "2" and "3", the mounting path length is reduced more and the mounting operation is made smoother when the mounting points 173 are concentrated as much as possible when seen in the two dimensional illustration as Fig. 4.

In the present embodiment, taking notice of this fact, the present embodiment adopts the concept of the aforementioned variance as a way of quantitatively evaluating a distribution spread of the mounting points 173, namely, a way of concentrating the distribution of the mounting points 173. Considering a rectangular region 177 which surrounds the distribution of mounting points 173, in terms of two dimensions with reference to Fig. 4, an appropriate

arrangement of parts cassettes 103a at the supply table 104 is obtained so that a multiplied value of a variance σ_1 of mounting points 173 in a longitudinal direction of the rectangular region 177 and a variance σ_2 of mounting points 173 in a lateral direction becomes
5 as small as possible.

In practice, the multiplied value of three variances corresponding to the number of dimensions is obtained for the distribution of mounting points 173 in three dimensions which is constituted of X and Y-coordinate values of mounting points on the
10 circuit board 2, and the Z-number, i.e., Z-coordinate values in the arrangement of parts cassettes 103a. Specifically, a product of three variances is obtained by obtaining the variance for X-coordinate values of mounting points on the circuit board 2, the variance for Y-coordinate values of mounting points, and the variance for
15 Z-coordinate values of mounting points. According to the present embodiment, the product of three variances is obtained with the utilization of a determinant of a three dimensional variance matrix as follows:

Expression 1

20
$$v_{ij} = (1/N) \sum_{a=r}^N (X_i(a) - \langle X_i \rangle) (X_j(a) - \langle X_j \rangle)$$

wherein $X_i(a)$ is an i element of the mounting point No. (a) , that is,

any of x, y and z-coordinate values, and $\langle X_i \rangle$ is a mean value of the i element. The matrix v is a symmetric matrix. As the three dimensional variance matrix is taken note as above, i and j are digits from 1 to 3 and v_{ij} itself is a substance digit in the matrix

5 which is expressed by:

Expression 2

$$\{ v_{11} \quad v_{12} \quad v_{13} \}$$

$$\{ v_{21} \quad v_{22} \quad v_{23} \}$$

$$\{ v_{31} \quad v_{32} \quad v_{33} \}$$

10 i is a number of row of the matrix and j is a number of column in the matrix. Each v value is calculated according to the Expression 1 and substituted for the above matrix, whereby the determinant of the matrix is obtained. In other words, the determinant is obtained according to the following Expression 3:

15 Expression 3

$$\text{Determinant} = v_{11} v_{22} v_{33} + v_{13} v_{21} v_{32} + v_{31} v_{12} v_{23}$$

$$- v_{13} v_{22} v_{31} - v_{11} v_{23} v_{32} - v_{12} v_{21} v_{33}$$

wherein v_{11} , v_{12} and the like as the substance figures in the matrix become the elements of the matrix.

20 The operation for obtaining the arrangement of parts cassettes 103a which makes the above variance small, namely, the

operation of step 100 will be more fully described now with reference to Fig. 5. Operations in steps 100 and 200 for obtaining the arrangement are controlled and executed by an arrangement optimizing part 181 included in the controller 180.

5 First at step 101, parts cassettes 103a are loaded and arranged onto the supply table 104 for each group so that the group of a higher rotational speed at the component holding device 105 is brought to a place with a smaller Z-number. Since the parts cassettes 103a are rearranged as will be described later because of the initial
10 arrangement, parts cassettes 103a within each group may be arranged in any order without being determined in the stage of step 101. At step 102, the number of changeover times in the arrangement of parts cassettes 103a on the supply table 104 is set to 0 as an initial value. At step 103, the above variance determinant value is obtained.
15 Specifically, variances are obtained corresponding to the X- and Y-coordinate values of the mounting points 173 and Z-numbers showing the location of parts cassettes 103a, and then a product of the three variances is obtained and substituted for Dold.

 At step 104, two parts cassettes 103a to be changed over
20 in the arrangement are selected with the use of random numbers. At step 105, the selected parts cassettes are replaced with each other.

At step 106, the variance determinant value is obtained for the parts cassettes 103a after the changeover at step 105, and is substituted for Dnew.

Next at step 107, the Dold and Dnew values are compared
5 with each other. At step 108, when the Dnew value is smaller than the Dold value, in other words, the arrangement becomes better, information on the arrangement of the parts cassettes 103a after the changeover is stored. On the other hand, when the Dnew value is larger than the Dold value, that is, the arrangement is made worse,
10 information is returned to original arrangement information of parts cassettes 103a before the changeover.

At next step 109, 1 is added to the number of changeover times of the arrangement and the process returns to step 105. Steps 105-109 are repeated until the number of changeover times
15 reaches a set value. The process is terminated at a time point when the number of changeover times becomes the set value. Arrangement information of parts cassettes 103a when the process is terminated is stored as temporary arrangement information into the storage 185 at step 110.

20 By carrying out the operation of step 100, such nature is observed on the average that the X or Y-coordinate values of the

mounting points 173 or its linear sum increase or decrease in accordance with an increase of the Z-numbers of the parts cassettes 103a. The nature is characteristic of the Z-direction arrangement of parts cassettes 103 which is obtained by the algorithm for carrying out step 100.

Step 200 will be depicted.

In step 200, the arrangement is optimized by adding correction to the temporary arrangement of parts cassettes 103a obtained in step 100. In the component mounting operation according to the above temporary arrangement, a phenomenon occurs in that the mounting paths at mounting points in the vicinity of the distribution of mounting points 173 such as shown in Fig. 4 elongate. The phenomenon is unfavorable from a view point of forming the path to be as short as possible. The operation of step 200 makes the correction to reduce this path loss. Since the temporary arrangement of parts cassettes 103a within the groups is obtained for each group in step 100 as described hereinabove, the correction operation in step 200 is also carried out to the temporary arrangement for each group.

~~Concept~~ The concept of the correction operation in step 200 is such that, while a starting point of the path which is, for example, one of the mounting points of the components supplied from

the parts cassette 103a arranged at $Z=0$ is fixed, different parts cassettes 103 which supply the components to be mounted to nearest mounting points within an X,Y-plane of the circuit board 2 with respect to the one mounting point are changed to be $Z=1$ sequentially from the one having a larger Z-coordinate value. The path loss to be generated in the vicinity of the distribution is reduced by repeating the above operation. Expressing in different words, the location of a second parts cassette 103a-2 is changed on the basis of a distance between a reference mounting position 178 of the circuit board 2 where the electronic component supplied from a first parts cassette 103a-1 present at the component holding position 171 or adjacent to the position 171 is to be mounted and an object mounting position 179 of the circuit board where the component supplied from the second parts cassette 103a-2 other than the first parts cassette 103a-1 is to be mounted. The arrangement of the parts cassettes is more optimized accordingly. To change the location of the second parts cassette 103a-2, the above distances are obtained sequentially while the second parts cassette 103a-2 for obtaining the distance is sequentially changed, and the second parts cassette 103a-2 which makes the distance shorter is brought next to the first parts cassette 103a-1.

A concrete algorithm in step 200 in the embodiment for

carrying out the above operation will be described with reference to Fig. 7. The operation in step 200 is carried out separately to a part of 0 to $n/2$ and a part of $(n+1)/2$ to n of the parts cassettes 103a arranged in one group with Z-numbers of 0-maximum n . The part of 0
5 | to $n/2$ will be described below by way of example—~~below~~.

The reason for carrying out step 200 separately to every half of the group is caused by the so-called retracement technique by step 200, whereby the distribution can be made small by carrying out the retracement with regard to each reference parts cassette 103a
10 | at the two regions.

At step 201, it is checked sequentially from the parts cassette 103a having the Z-number, i.e., the parts cassette 103a arranged at Z-coordinate value of 0 whether or not the parts cassette 103a contains one or two electronic components to supply. Step 201
15 | advances to next step 202 when the parts cassette 103a has the electronic component(s), whereas the above operation is carried out again by increasing the Z-coordinate value one by one when the parts cassette 103a contains no electronic component. At step 202, the Z-coordinate value of the parts cassette 103a where the presence of
20 | one or two electronic components is confirmed first at step 201 is made to be a reference Z1. At step 203, the mounting point 173 of

the electronic component supplied from the parts cassette 103a disposed at the reference Z1 is made to be the reference mounting position 178.

At step 204, it is checked sequentially from the parts cassette 103a having the Z-coordinate value of $n/2$ whether or not the parts cassette 103a contains one or two electronic components to supply. The step goes to step 205 when the parts cassette 103a contains electronic component(s). Without electronic component(s) contained, the presence/absence of electronic component(s) is confirmed in the same manner as above by reducing the Z-coordinate value one by one. At step 205, the Z-coordinate value of the parts cassette 103a where the presence of one or two components to be supplied is confirmed first at step 204 is made to be an object Z2. At step 206, the mounting point 173 of the electronic component supplied from the parts cassette 103a arranged at the object Z2 is made to be the object mounting position 179.

At step 207, the distance on the X,Y-plane between the reference mounting position 178 and the object mounting position 179 is obtained. When there are two electronic components to be supplied from the same parts cassette 103a, as shown in Fig. 8, a second distance 192 on the X,Y-plane between two object mounting positions 179 is added

to a first distance 191. At step 208, the distance value obtained at step 207 is stored as L, and 1 is subtracted from the Z-coordinate value to return to step 204. The step moves on to step 209 when the Z-coordinate value of the object Z2 becomes the Z-coordinate value of the reference Z1. At step 208, if there is already the obtained distance value L, an existing distance value Lo is compared with the distance value Ln obtained this time, and the present distance value Ln is rendered the distance value L only when the present distance value Ln is smaller than the existing distance value Lo.

10 At step 209, the parts cassette 103a present at the Z-coordinate value of the object Z2 which provides the smallest distance value L is arranged to a Z-coordinate position of the reference Z1+1. Parts cassettes 103a originally arranged at the reference Z1+1 position and the Z-coordinate positions thereafter are
15 moved backward each by one position. Then the step returns to step 201. The correction operation is terminated at step 210 when the reference Z1 reaches $n/2$.

 The arrangement of parts cassettes 103a disposed at the remaining $(n+1)/2$ to n of Z-coordinate positions is corrected in the
20 same manner as above.

By the foregoing operation, an arrangement having a high

possibility of providing the shortest mounting path can be obtained for parts cassettes 103a in one group. The arrangement of parts cassettes 103 obtained by the above operation will be named an initial component cassettes arrangement 201.

5 Similar to the above, an arrangement having a high possibility of providing the shortest mounting path is obtained for every group of parts cassettes 103a.

Step 300 will be described hereinafter.

10 In step 300, such path is obtained that reduces the component mounting path to the circuit board 2 more under the arrangement of parts cassettes 103a optimized in the above steps 100 and 200. In the present embodiment, a concept of a mounting order is introduced because an optimum mounting path is considered with the arrangement of parts cassettes 103a separated. The mounting order
15 provides an order or sequence in which the components are mounted to the mounting points 173. A three-dimensional mounting path is determined when the mounting order is combined with the arrangement of parts cassettes 103a. That is, the mounting path changes although the mounting order does not change when
20 the arrangement of parts cassettes 103a is changed.

According to the operation in the embodiment in step 300,

two are selected from mounting paths for connecting two mounting points 173 and then the two mounting paths are recombined, thereby selecting the path having a shorter mounting path length through comparison between before and after the recombination, whereby the mounting path is optimized. A concrete algorithm in the embodiment in step 300 will be described below with reference to Figs. 9-11. Figs. 10 and 11 are halves of a diagram divided because of a sheet size, which continue at marks I-IV. The operation in step 300 for obtaining the component mounting path is controlled and carried out by a mounting path optimizing part 182 included in the controller 180.

At step 301 in Fig. 9, an initial mounting order O1 is applied, which may be any order. At step 302, distances from each of mounting points 173 to all of mounting points 173 present on the circuit board 2, for example, each distance from a first mounting point to each of a second, a third, ... and an n mounting points, each distance from the second mounting point to each of the third, a fourth, ... and the n mounting points, and the like are obtained and stored. Moreover, an initial mounting path P1 is obtained on the basis of the initial mounting order O1 under the arrangement of parts cassettes 103a obtained in the foregoing steps 100 and 200. At step 303, a path length of the initial mounting path P1 is obtained with the use of the above

distances between mounting points 173, and the initial mounting path P₁ and the path length of the initial mounting path P₁ are substituted for a "mounting path P" and an "optimum mounting path length L_{opt}" respectively. At step 304, the initial mounting order O₁ is substituted for a "mounting order O" and an "optimum mounting order O_{opt}". At step 305, the initial component cassettes arrangement Z₀₁ which is the arrangement of parts cassettes 103a obtained in steps 100 and 200 is substituted for a "component cassettes arrangement Z₀" and an "optimum component cassettes arrangement Z_{Oopt}". At step 306, 0 is substituted for the "number of recombination times (a)" within the operation at step 307 to be described below.

At step 307, for optimizing the mounting order O through optimization of the mounting path P, the mounting order O is optimized with the utilization of the recombination method, thereby obtaining a new mounting order O_{new} and a new mounting path P_{new}. As will be detailed below, the recombination method is such that two unit paths are selected from the mounting path, a new path is formed by changing starting points and end points of the selected unit paths, and the new path is adopted if the new path has a shorter path length than that of the path before the recombination. This recombination method will be discussed with reference to steps 320-330 shown in Figs. 10

and 11, and Figs. 12-14.

At steps 320 and 321, i is made to be a first mounting point, that is, $i=1$ is set and a mounting point j is made to be $j=i+1$ in the initial mounting order $O1$. A mounting point to which the component is mounted next to the mounting point i is a mounting point i_{Bottom} , and a mounting point to which the component is mounted next to the mounting point j is a mounting point j_{Bottom} . At step 322, a first unit path $u1$ for connecting the mounting points i and i_{Bottom} , and a second unit path $u2$ for connecting the mounting points j and j_{Bottom} are selected to be objects of recombination. In the following description, for example, the first unit path $u1$ is notated by $u1 (i, i_{\text{Bottom}})$ and the second unit path is notated by $u2 (j, j_{\text{Bottom}})$. The mounting order will be more specifically described with reference to Fig. 12. ~~Supposed~~ Suppose that there are five mounting points 173-1 to 173-5 and the initial mounting order is set to be an order from the mounting point 173-1 to the mounting point 173-5, for instance, the mounting point j becomes the mounting point 173-2 when the mounting point 173-1 is set as the mounting point i . Also the mounting point 173-2 corresponds to the mounting point i_{Bottom} and the mounting point 173-3 corresponds to the mounting point j_{Bottom} . Under the above condition, the first unit path $u1$ is expressed by the notation

(173-1, 173-2) and the second unit path u_2 is expressed by the notation (173-2, 173-3).

At step 323, a sum of the lengths of the first unit path u_1 (173-1, 173-2) and the second unit path u_2 (173-2, 173-3) is obtained
5 with reference to distance information between each mounting point 173 stored at step 302. The sum is stored into "Dorg".

At step 324, before the unit path u_1 (i , i_{Bottom}) and the unit path u_2 (j , j_{Bottom}) selected as objects of recombination are actually recombined, a unit path length after the recombination is
10 obtained on the basis of distance information of mounting points 173 stored at step 302, and is substituted for "Dpara".

At step 325, "Dorg" value is compared with "Dpara" value. The two unit paths are actually subjected to recombination at step 326 only when "Dpara" value is smaller than "Dorg".

15 At step 326, a mounting path composed of a third unit path u_3 (i , j) and a fourth unit path u_4 (i_{Bottom} , j_{Bottom}) is formed by replacing the end points and the starting points of the above unit path u_1 (i , i_{Bottom}) and unit path u_2 (j , j_{Bottom}) respectively, so that the formed mounting path is reflected onto the mounting order.

20 In the example shown in Fig. 12, since the mounting point i_{Bottom} and the mounting point j are the same mounting point (173-2)

and consequently "Dorg" value and "Dpara" value are equal, step 326 is not carried out and the process proceeds to step 327.

The operation of reflecting the mounting path to the mounting order at step 326 as above will be detailed. ~~Supposed~~Suppose that mounting points 173-1 to 173-9 are first allotted from the mounting point 173-1 to the mounting point 173-9 corresponding to from a mounting order No. 1 to a mounting order No. 9, the mounting path traces a sequence from the mounting point 173-1 to the mounting point 173-9 as shown in Fig. 15. The mounting path is determined by this sequence. Then the mounting path is optimized by the recombination as described at steps 302-307.

When the mounting path of the example shown in Fig. 15 is optimized, since paths (173-2, 173-7) and (173-3, 173-8) could shorten the path length more than the paths (173-2, 173-3) and (173-7, 173-8), the mounting path is hence changed to the paths (173-2, 173-7) and (173-3, 173-8).

However, even when the mounting path is changed as above, electronic components are mounted by the same mounting path as that of Fig. 15 unless the mounting order is changed. The mounting order is designated by incrementing program steps. Accordingly, at step 326, mounting points are switched

correspondingly to the mounting path so that the optimized mounting path matches with the mounting order designated by the increment. The switching is carried out to continue the mounting order between the optimized two unit paths and a path present between the two paths.

5 Namely, when the paths (173-2, 173-3) and (173-7, 173-8) are merely changed to the paths (173-2, 173-7) and (173-3, 173-8) in the above example, the mounting order in the paths (173-2, 173-7) and (173-3, 173-8) and the path from the mounting point 173-3 to the mounting point 173-7 cannot continue as in Fig. 16. That is, the
10 mounting order diverges to both the mounting point 173-4 and the mounting 173-8 from the mounting point 173-3, and furthermore, the mounting order collides from both the mounting point 173-6 and the mounting point 173-2 at the mounting point 173-7.

For securing continuity of the mounting order, namely,
15 for reflecting the optimized mounting path to the mounting order, mounting points corresponding to the mounting orders Nos. 3-7 are changed in the above example as shown in Fig. 17. Specifically, mounting points 173-3 to 173-7 corresponding to the mounting orders Nos. 3-7 are inverted to be mounting points 173-7 to 173-3
20 correspondingly to the mounting orders Nos. 3-7 as indicated in Fig. 18 before the optimization. Since the optimized mounting path is

reflected to the mounting order in this manner at step 326, the mounting operation carried out from the mounting order No. 1 to the mounting order No. 9 will follow the optimized path of Fig. 17.

Step 327 is carried out in the case where the mounting point j is smaller than a value obtained by subtracting 1 from a total number of mounting points. When the mounting point j is larger than the value, the process moves on to step 328. After 1 is added to the mounting point j at step 327, the step returns to step 322. Concretely, the mounting point j changes from the mounting point 173-2 to the mounting point 173-3 and the mounting point jBottom becomes the mounting point 173-4 as shown in Fig. 13 when 1 is added to the mounting point j. Then, at step 322, unit paths u1 (173-1, 173-2) and u5 (173-3, 173-4) are selected as objects of recombination. At step 323, a sum of the unit paths u1 and u5 is obtained on the basis of the distance information. At step 324, by the recombination from paths (i, iBottom) and (j, jBottom) to paths (i, j) and (iBottom, jBottom) as above, a sum of a unit path u6 (173-1, 173-3) and a unit path u7 (173-2, 173-4) as paths after the recombination of the above unit paths u1 and u5 is obtained on the basis of the distance information. The steps 325 and 326 are carried out then. The recombination is executed only when the "Dpara" value is smaller, whereby a mounting path composed

of the unit path u_6 (173-1, 173-3) and unit path u_7 (173-2, 173-4) is formed. Step 327 is subsequently carried out again.

At step 327, there is also a unit path obtained in the present example by adding 1 to the mounting point j other than the
5 above unit path (173-3, 173-4), in which the mounting point j becomes the mounting point 173-4 and the mounting point j_{Bottom} becomes the mounting point 173-5 as shown in Fig. 14. However, since the total number of mounting points is 5 in the example and the mounting point
| j_{Bottom} comes not to exist if the mounting point j is made to be the
10 mounting point 173-5, the mounting point j can be up to the mounting point 173-4 at step 327. Therefore, at step 322, unit paths to be objects of recombination are the above (173-1, 173-2) and (173-3, 173-4), and (173-1, 173-2) and (173-4, 173-5). Steps 322-326 are carried out also for the unit paths (173-1, 173-2) and (173-4, 173-5).

15 A path of a shorter mounting path length is thus obtained by changing the mounting point j and obtaining the path length of the path after the recombination at each time.

Step 327 moves to step 328 at a time point when the mounting point j exceeds the mounting point 173-4.

20 At step 327, the shorter mounting path is obtained by changing only the mounting point j without changing the mounting point

i. In contrast, at step 328, the shorter mounting path is obtained by adding 1 to the mounting point i thereby changing the mounting point i as well and then returning to the step 321. More specifically, in the above explanation up to step 327, while the comparison is made sequentially in an order of between unit paths (173-1, 173-2) and (173-2, 173-3), between unit paths (173-1, 173-2) and (173-3, 173-4), between unit paths (173-1, 173-2) and (173-4, 173-5), when and since step 328 is executed, steps 322-327 are carried out also for each of between the unit paths (173-2, 173-3) and (173-3, 173-4) and between unit paths (173-2, 173-3) and (173-4, 173-5).

At step 328, since the mounting point j becomes the mounting point 173-5 and the mounting point jBottom comes not to exist when the mounting point i is made to be the mounting point 173-4, the mounting point i is up to the mounting point 173-3, i.e., a value reduced by 2 from the total number of mounting points. The step advances to step 329 when the mounting point i exceeds the mounting point 173-3.

A shorter mounting path is obtained in the above manner at step 328 by changing both the mounting point i and the mounting point j.

At step 329, a total mounting path length L is obtained for the path after the recombination obtained by the operations up to step 328. The total mounting path length L is compared with the "optimum mounting path length (L_{opt})" at step 330. As a result of the comparison, the process is terminated when both values agree. The step returns to step 320 by adding 1 to the "number of recombination times (a)" when the values disagree, so that the above-described recombination operation is carried out again. The reason for carrying out the same operation is because it is unclear whether or not the path is shortest although the path is naturally shortened by the execution of the operations up to step 330. In the case where the total mounting path length L becomes slightly shorter than the optimum mounting path length L_{opt} which corresponds to the total mounting path length in the previous operation at every recombination time, the process is terminated when the "number of recombination times (a)" reaches a set value to save a processing time.

The operation of step 300 completes by the operations from the above step 320 to step 329.

Step 400 will be described with reference to Figs. 19 and 20 which are halves of a flow chart divided because of a sheet size and continue at marks V and VI.

Step 400 is an operation for adding correction to obtain a better component mounting order, in which two arbitrary ~~two of~~ parts cassettes 103a arranged in steps 100 and 200 are rearranged, and the mounting path, the mounting order and the mounting path length are
5 obtained again for the rearranged parts cassettes.
This will be depicted in detail below.

At step 401, two arbitrary ~~two~~ parts cassettes 103a are selected with the use of random numbers in the arrangement of parts cassettes 103a obtained by step 200. The two parts cassettes are
10 replaced in the arrangement. At next step 402, the mounting order O obtained by the foregoing step 300 is adopted as the "optimum mounting order Oopt", and the component cassettes arrangement ZO by the component cassettes arrangement changed at step 401 is substituted for the "optimum component cassettes arrangement ZOopt". At step
15 403, step 307 is executed for the changed arrangement to optimize the mounting order by the recombination method. The recombination is carried out until the number of recombination times (a) reaches a set value. At step 404, a new mounting path length Lnew of a new mounting path Pnew obtained at step 403 is obtained.

20 At step 405, the present optimum mounting path length Lopt is compared with the new mounting path length Lnew. When the optimum

mounting path length L_{opt} is shorter as a result of the comparison, the new mounting path length L_{new} , the changed component cassettes arrangement ZO and a mounting order O_{new} based on the changed component cassettes arrangement are discarded at step 406. On the other hand,
5 when the new mounting path length L_{new} is shorter, the mounting order O_{new} is substituted for the "optimum mounting order O_{opt} ", the component cassettes arrangement ZO is substituted for the "optimum component cassettes arrangement ZO_{opt} " and the new mounting path length L_{new} is substituted for the "optimum mounting path length L_{opt} "
10 at step 407.

At step 408, it is determined whether or not the rearrangement of arbitrary two parts cassettes 103a at step 401 is carried out by the set number of times. In the case where the number is smaller than the set number of times, the step returns to step 401.
15 When the rearrangement is carried out by the set number of times, the step goes to step 409, where the optimum component cassettes arrangement and the optimum mounting order O_{opt} at this time are stored as the optimum component cassettes arrangement and the optimum mounting order respectively, thereby terminating step 400.

20 As described hereinabove, according to the present embodiment, the arrangement of parts cassettes 103a is obtained with

the relation to the mounting positions on the circuit board 2 taken into account in steps 100 and 200. Therefore, the mounting time can be shortened in comparison with the conventional art. Moreover, the mounting path to the mounting positions is optimized by executing step 5 300 and further step 400 under the obtained arrangement of parts cassettes 103a, so that the mounting order can be optimized. The mounting time can accordingly be shortened furthermore as compared with the conventional art.

In Fig. 25, a movement amount of each part when the components are mounted by the component mounting order optimization method according to the above-described embodiment is compared with a movement amount by mounting methods A and B other than the present embodiment. An "XY movement distance" shown in Fig. 25 is the mounting path length on the circuit board expressed by the unit of 10 mm, and a "three-dimensional movement distance" is a total movement distance expressed by the unit of mm of the nozzle 105b required for 15 the mounting operation when each Z-number of the parts cassettes 103 arranged by a pitch of 22mm is converted to the length. A "total Z shift" is a movement distance of parts cassettes 103a counted in units 20 of Z-numbers. For instance, ~~supposed~~ suppose that the parts cassettes 103a are disposed at Z-numbers 1, 3 and 5 and electronic components

are taken out from the parts cassettes 103a sequentially from Z-numbers 1→3→5, the "total Z shift" becomes 4 (=2+2). As is apparent from Fig. 25, although the "total Z shift" is smaller in the mounting method A than in the present embodiment in some cases, the "three-
5 dimensional movement distance" showing the total movement distance is shorter in the present embodiment. Therefore, the present embodiment can shorten the mounting path as a whole in comparison with the conventional art, thus enabling shortening of the mounting time in comparison with the conventional art.

10 After the component mounting order optimized by the above-discussed component mounting order optimization method is obtained, the controller 180 controls driving of the drive unit 104a of the supply table 104 according to the component mounting order to locate a desired parts cassette 103a to the component holding position
15 171, and also controls driving of the drive units 109a and 109b of the orthogonal table 109 to position a desired mounting point 173 of the circuit board 2 to the component mounting position 172, thereby carrying out the component mounting operation to the circuit board 2. At this time, after the operation in step 400 ends in the case
20 where the operations up to step 400 are carried out, or after the operation in step 300 ends when the operations up to step 300 are

carried out without carrying out step 400, the worker arranges each parts cassette 103a onto the supply table 104 in accordance with the optimized arrangement of parts cassettes 103a which is obtained in step 400 or 300. After the parts cassettes are arranged, the mounting operation for electronic components to the circuit board 2 is carried out by the component mounting apparatus 101 in accordance with the optimized component mounting order.

In the case where the operations up to step 300 are carried out excluding step 400, after steps 100 and 200 end, the worker may arrange each parts cassette 103a onto the supply table 104 in accordance with the optimized arrangement of parts cassettes 103a without waiting for the end of step 300.

The component shift device 105 of the so-called rotary type is adopted as an example of a component shift device in the above embodiment. But the component shift device installed in the component mounting apparatus 101 is not limited to the rotary type, the component shift device such as a component insertion device which transfers the components from the parts cassettes 103a to the circuit board 2 without shifting the components along a circular path can be installed.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference

to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims
5 unless they depart therefrom.

ABSTRACT

A controller (180) optimizes an arrangement of component supply parts installed in a component supply unit while position
5 information of mounting points on a circuit board is taken into account (S100 and S200), and then optimizes a mounting path to the circuit board under the arrangement (S300). Since the position information of mounting points is taken into account in obtaining the arrangement of component supply parts, wasteful mounting paths are reduced in
10 comparison with the case of optimizing the mounting path on only the circuit board as in the conventional art, so that the mounting time can be shortened.